

10.0 Cm³ Of A Strong Acid Solution Has A PH Of 3.What Will Be The PH Of The Solution When It Is Diluted

10.0 Cm³ Of A Strong Acid Solution Has A PH Of 3. What Will Be The PH Of The Solution When It Is Diluted

Understanding how dilution affects the pH of a strong acid solution is fundamental in chemistry. When a strong acid solution is diluted, its concentration decreases, which in turn influences the pH value. This article explores the principles behind pH calculation, the impact of dilution on pH, and provides step-by-step guidance to determine the pH after dilution for the given scenario of 10.0 cm³ of a strong acid with an initial pH of 3.

Introduction to pH and Strong Acids

What Is pH?

pH is a logarithmic scale used to specify the acidity or alkalinity of an aqueous solution. It is defined as:

$$\text{pH} = -\log [\text{H}^+]$$

where $[\text{H}^+]$ is the molar concentration of hydrogen ions in the solution.

- pH less than 7: Acidic solution
- pH equal to 7: Neutral solution
- pH greater than 7: Basic or alkaline solution

Strong Acids and Their Characteristics

Strong acids, such as hydrochloric acid (HCl), dissociate completely in water:



This complete dissociation means that the concentration of $[\text{H}^+]$ directly corresponds to the initial molarity of the acid.

Understanding the Given Scenario

The problem states:

- Volume of the initial strong acid solution: 10.0 cm^3
- Initial pH of the solution: 3

From this information, we can determine the initial molar concentration of hydrogen ions, which is crucial for calculating the pH after dilution.

Calculating the Initial Concentration of Hydrogen Ions

Step 1: Convert pH to $[H^+]$ Concentration

Given:

$$[\text{pH} = 3]$$

Using the formula:

$$[[H^+] = 10^{-\text{pH}} = 10^{-3} = 1 \times 10^{-3} \text{ mol/L}]$$

This indicates the initial molar concentration of hydrogen ions in the solution is $(1 \times 10^{-3} \text{ mol/L})$.

Step 2: Determine the Moles of Hydrogen Ions in 10.0 cm^3

Convert volume to liters:

$$[10.0 \text{ cm}^3 = 10.0 \times 10^{-3} \text{ L} = 0.010 \text{ L}]$$

Calculate moles of $[H^+]$:

$$[\text{Moles of } H^+ = [H^+] \times \text{Volume} = (1 \times 10^{-3}) \times 0.010 = 1 \times 10^{-5} \text{ moles}]$$

This is the total amount of hydrogen ions present initially.

Determining the pH After Dilution

The key to understanding the effect of dilution on pH lies in the concept that, for a strong acid, the concentration of hydrogen ions is directly proportional to the molarity of the acid.

Step 1: Understand the Dilution Process

When a solution is diluted, additional solvent (usually water) is added, increasing the total volume while the amount of solute remains constant. This results in a decrease in molarity.

Suppose the solution is diluted to a new volume (V_{final}) . The initial moles of hydrogen ions (n_{initial}) stay the same, but the concentration becomes:

$$[H^+]_{\text{final}} = \frac{n_{\text{initial}}}{V_{\text{final}}}$$

Step 2: Calculate the New Concentration

Since the initial moles of hydrogen ions are known, the new concentration after dilution depends on the final volume.

Example:

- If the solution is diluted to a volume (V_{final}) , then:

$$[H^+]_{\text{final}} = \frac{1 \times 10^{-5} \text{ moles}}{V_{\text{final}} \text{ L}}$$

- The new pH is then:

$$\text{pH}_{\text{final}} = -\log [H^+]_{\text{final}}$$

How to Calculate the pH After Dilution: Step-by-Step Guide

Step 1: Identify the Final Volume of the Diluted Solution

The problem should specify or imply the final volume after dilution. For illustration, let's consider a common case:

- Suppose the initial 10.0 cm³ (0.010 L) solution is diluted to 100.0 cm³ (0.100 L).

Step 2: Calculate the Final Concentration of $[H^+]$

Since moles of hydrogen ions are conserved:

$$[H^+]_{\text{final}} = \frac{1 \times 10^{-5} \text{ moles}}{0.100 \text{ L}} = 1 \times 10^{-4} \text{ mol/L}$$

Step 3: Determine the Final pH

Using the concentration:

$$\text{pH}_{\text{final}} = -\log(1 \times 10^{-4}) = 4$$

Thus, after diluting to 100 mL, the pH increases from 3 to 4.

General Formula for pH After Dilution

Given:

- Initial volume: V_{initial}
- Initial pH: $\text{pH}_{\text{initial}}$
- Final volume: V_{final}

The steps to find the new pH are:

1. Calculate initial $[H^+]$:

$$[H^+]_{\text{initial}} = 10^{-\text{pH}_{\text{initial}}}$$

2. Calculate initial moles:

$$n_{\text{initial}} = [H^+]_{\text{initial}} \times V_{\text{initial}}$$

3. Find the new concentration:

$$[H^+]_{\text{final}} = \frac{n_{\text{initial}}}{V_{\text{final}}}$$

4. Calculate the new pH:

$$\text{pH}_{\text{final}} = -\log [H^+]_{\text{final}}$$

Practical Examples and Applications

- Dilution in Laboratory Settings: Chemists often dilute concentrated acids to safer, manageable concentrations. Knowing how pH changes helps ensure safety and precision.
- Buffer Solutions: Understanding pH changes during dilution is crucial when working with buffer solutions that resist pH change.
- Environmental Chemistry: Dilution of pollutants such as acids in water bodies affects their acidity, impacting aquatic life.

Limitations and Important Considerations

- For Strong Acids: The assumption that dissociation is complete simplifies calculations; the $[H^+]$ is directly related to molarity.
- For Weak Acids: The calculation becomes more complex since dissociation is not complete and depends on the acid dissociation constant (K_a).
- Dilution Accuracy: Precise measurements of volume are necessary for accurate pH calculations.
- Temperature Effects: pH is temperature-dependent; calculations assume standard conditions ($\sim 25^\circ C$).

Summary and Key Takeaways

- The initial pH of 3 indicates a hydrogen ion concentration of (1×10^{-3}) mol/L.
- Dilution decreases the concentration of $[H^+]$, resulting in an increase in pH.
- The new pH can be calculated by understanding the conservation of moles and the change in volume.
- As a general rule, every tenfold dilution increases the pH by 1 in the case of strong acids.

Conclusion

Understanding the relationship between dilution and pH is vital for chemical safety, laboratory experiments, and environmental studies. In the scenario where 10.0 cm^3 of a

strong acid solution with a pH of 3 is diluted, the pH increases proportionally to the change in concentration. By applying the principles of molarity, logarithms, and conservation of moles, chemists can accurately predict the pH of the solution post-dilution. Whether diluting for safety, measurements, or environmental reasons, mastering these calculations ensures precision and safety in chemical handling.

Remember: The fundamental concept is that pH depends logarithmically on hydrogen ion concentration. Dilution reduces concentration, thus increasing pH, and the precise change can be calculated using the steps outlined above.

Frequently Asked Questions

What is the initial pH of 10.0 cm³ of a strong acid solution with a pH of 3?

The initial pH is 3, as given in the problem statement.

How does diluting a strong acid solution affect its pH?

Diluting a strong acid decreases its concentration, which increases its pH, making the solution less acidic.

What is the relationship between concentration and pH in a strong acid solution?

In a strong acid, pH is directly related to the concentration of hydrogen ions; as concentration decreases, pH increases.

How can we calculate the new pH after dilution of a strong acid solution?

Use the dilution formula $C_1V_1 = C_2V_2$ to find the new concentration, then calculate pH as $-\log[H^+]$, where $[H^+]$ is the molar concentration of hydrogen ions.

If the original solution has a pH of 3, what is its hydrogen ion concentration?

The hydrogen ion concentration is 10^{-3} mol/L.

What happens to the pH if the solution is diluted by a factor of 10?

The pH increases by approximately 1 unit, changing from 3 to 4.

Can we determine the exact pH after dilution without knowing the dilution factor?

No, the exact pH after dilution depends on the degree of dilution; without that, only general trends can be described.

Why does diluting a strong acid lead to an increase in pH?

Because dilution reduces the concentration of hydrogen ions, decreasing acidity and increasing pH.

What is the significance of pH in understanding acid strength and concentration?

pH provides a logarithmic measure of hydrogen ion concentration, helping to quantify acidity and concentration of solutions.

Additional Resources

Understanding the Impact of Dilution on pH of a Strong Acid Solution

When dealing with acids and their solutions, pH is a fundamental concept that quantifies the acidity or alkalinity of the solution. In this detailed review, we'll explore what happens to the pH of a strong acid solution when it is diluted, starting with a specific example: a 10.0 cm³ of a strong acid solution with an initial pH of 3. Let's delve into the chemistry principles underpinning this scenario, the calculations involved, and the broader implications.

What Is pH and How Is It Related to Hydrogen Ion Concentration?

pH is a logarithmic scale used to specify the acidity or basicity of an aqueous solution. It is defined as:

$$\text{pH} = -\log [\text{H}^+]$$

where $[\text{H}^+]$ represents the molar concentration of hydrogen ions in the solution, measured in moles per liter (M).

Key points:

- A pH of 7 is considered neutral (pure water at 25°C).

- pH less than 7 indicates acidity.
- pH greater than 7 indicates alkalinity.

Since pH is logarithmic, small changes in pH correspond to significant changes in hydrogen ion concentration.

Initial Data and Its Significance

Given:

- Volume of initial solution: 10.0 cm³ (which is 0.010 L)
- Initial pH: 3

Using the definition of pH:

$$[\mathrm{H}^+]_{\text{initial}} = 10^{-\text{pH}} = 10^{-3} = 1 \times 10^{-3} \text{ M}$$

This indicates that in the initial solution, the hydrogen ion concentration is 0.001 mol/L.

Note: Since the solution is a strong acid, it dissociates completely, meaning the molarity of the acid is equal to the hydrogen ion concentration.

Calculating the Number of Moles of Acid in the Initial Solution

To understand how dilution affects the pH, it's crucial to consider the total amount of acid present.

Number of moles:

$$\begin{aligned} \text{moles of } \mathrm{H}^+ &= [\mathrm{H}^+] \times \text{volume} \\ &= 1 \times 10^{-3} \text{ mol/L} \times 0.010 \text{ L} \\ &= 1 \times 10^{-5} \text{ mol} \end{aligned}$$

This is the total quantity of hydrogen ions (and hence acid molecules) initially present in the solution.

Understanding Dilution and Its Effect on pH

Dilution involves adding solvent—usually water—to decrease the concentration of solutes in

a solution without changing the amount of solute present.

Key principles:

- The total moles of acid (or hydrogen ions) remain unchanged during dilution.
- The molarity of the hydrogen ions decreases proportionally with the increase in volume.
- pH depends on the hydrogen ion concentration, which changes with dilution.

Calculating the pH After Dilution

Suppose we dilute the initial solution by adding a certain volume of water. The question is: What will be the pH after dilution?

Step 1: Determine the new volume after dilution

Let's assume the initial volume is $(V_1 = 0.010)$ L.

Suppose the solution is diluted to a new volume (V_2) . The new molarity of hydrogen ions:

$$[\mathrm{H}^+]_{\text{new}} = \frac{\text{moles of } \mathrm{H}^+}{V_2}$$

Since the total moles of hydrogen ions are conserved:

$$\text{moles of } \mathrm{H}^+ = 1 \times 10^{-5} \text{ mol}$$

then:

$$[\mathrm{H}^+]_{\text{new}} = \frac{1 \times 10^{-5}}{V_2}$$

and the new pH:

$$\text{pH}_{\text{new}} = -\log \left(\frac{1 \times 10^{-5}}{V_2} \right)$$

which simplifies to:

$$\begin{aligned} \text{pH}_{\text{new}} &= -\log (1 \times 10^{-5}) + \log V_2 \\ &= 5 + \log V_2 \end{aligned}$$

(assuming (V_2) in liters).

Note: To get the pH, the volume must be expressed in liters.

Practical Example: Diluting to Different Volumes

Let's analyze specific scenarios to understand how pH changes with various dilutions.

Scenario 1: Dilution to 100.0 cm³

- New volume, $V_2 = 100.0 \text{ cm}^3 = 0.100 \text{ L}$

Calculate:

$$[\text{H}^+]_{\text{new}} = \frac{1 \times 10^{-5}}{0.100} = 1 \times 10^{-4} \text{ M}$$

pH:

$$\text{pH} = -\log(1 \times 10^{-4}) = 4$$

Result: The pH increases from 3 to 4 upon diluting to 100 cm³.

Scenario 2: Dilution to 1,000.0 cm³

- $V_2 = 1000.0 \text{ cm}^3 = 1.000 \text{ L}$

Calculate:

$$[\text{H}^+] = \frac{1 \times 10^{-5}}{1.000} = 1 \times 10^{-5} \text{ M}$$

pH:

$$-\log(1 \times 10^{-5}) = 5$$

Result: pH increases to 5.

Scenario 3: Dilution to 10,000.0 cm³

- $V_2 = 10,000 \text{ cm}^3 = 10.0 \text{ L}$

Calculate:

$$[\text{H}^+] = \frac{1 \times 10^{-5}}{10} = 1 \times 10^{-6} \text{ M}$$

pH:

$$6$$

Observation: As the solution is diluted further, pH increases logarithmically.

General Formula for pH After Dilution

From the calculations above, we see a pattern:

$$\boxed{\text{pH}_{\text{diluted}} = \text{pH}_{\text{initial}} + \log \left(\frac{V_2}{V_1} \right)}$$

where:

- $\text{pH}_{\text{initial}} = 3$
- $V_1 = 0.010 \text{ L}$ (initial volume)
- V_2 = final volume after dilution

This formula applies because the acid is strong and dissociates completely, making hydrogen ion concentration directly proportional to molar concentration.

Implications and Limitations

Implications:

- For dilutions where the acid remains strong and fully dissociated, the pH increases logarithmically with volume.
- This knowledge allows precise control over acidity in laboratory and industrial processes.
- The relationship underscores the importance of volume in determining solution pH after dilution.

Limitations:

- The formula assumes the acid remains strong and fully dissociates at all concentrations.
- At very high dilutions, the acid's behavior may deviate slightly due to activity coefficients and ion interactions.
- For weak acids or bases, the dissociation is incomplete, and calculations require different approaches involving equilibrium constants.

Broader Perspectives: Real-World Applications and Considerations

1. Titration and Analytical Chemistry:

Understanding how pH varies with dilution is critical in titrations, where precise pH measurements determine the endpoint.

2. Environmental Chemistry:

Dilution effects influence natural water bodies' pH levels, affecting ecosystems and water treatment.

3. Industrial Processes:

Manufacturing of chemicals, pharmaceuticals, and food products often involves acid solutions, where pH control is vital.

4. Buffer Solutions:

In systems where pH stability is necessary, dilution effects must be considered alongside buffering capacity.

Summary and Conclusion

Starting with a 10.0 cm³ (0.010 L) strong acid solution of pH 3, the key takeaways are:

- The initial hydrogen ion concentration is (1×10^{-3}) M.
- The total moles of hydrogen ions are (1×10^{-5}) mol.
- When diluted, the number of moles remains constant, but the concentration decreases proportionally to the increase in volume.
- The pH after dilution can be calculated using the relationship:

$\frac{1}{\text{pH}_2} = \frac{V_1}{V_2} \times 10^{\text{pH}_1}$

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